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# Atacama Large Millimeter/Submillimeter Array (ALMA) Observatory

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**Abstract:** The Atacama Large Millimeter/Submillimeter Array (ALMA) is an interferometer array of 54_12m and 12_7m antennas, ALMA science will transform our vision of the cold, dusty, and gaseous universe, from extrasolar planets to the youngest galaxies. Receivers for the ALMA are designed to include 10 frequency bands. (ALMA) is an international effort to construct an instrument capable of matching the exquisite imaging properties of optical space telescopes at millimeter and submillimeter wavelengths. So this paper presents a review on different observatories of telescope.

**Keywords:** Telescopes, submillimeter, high angular resolution, interferometric.

## I. INTRODUCTION

Radio telescopes have been built for use in the field of radio astronomy to observe the Universe in the radio portion of the electromagnetic spectrum. Such an instrument, or collection of instruments, with supporting facilities such as control centres, visitor housing, data reduction centers, and/or maintenance facilities are called radio observatories. The ALMA is the precision multitool for mapping the once hidden, detailed activities of the Cosmos [1]. ALMA is a premier telescope for studying the first stars and galaxies that emerged from the cosmic "dark ages" billions of years ago.

We find them at great cosmic distances, with most of their light stretched out to millimeter and submillimeter wavelengths by the expansion of the Universe [2]. In the more nearby Universe, ALMA provides an unprecedented ability to study the processes of star and planet formation. ALMA allows scientists to learn in detail about the complex molecules of the giant clouds of gas and dust that spawn stars and planetary systems. GLOBAL PROJECT: The ALMA, an international astronomy facility, is a partnership of East Asia, Europe and North America in cooperation with the Republic of Chile [3]. ALMA is an international partnership among Europe, the United States, Canada, Japan, South Korea, Taiwan, and Chile.

## II. ALMA OBSERVATORY

Atacama Large Millimeter Array (ALMA) is a radio observatory at an elevation of 5000 meters (16,405ft) located on Chile. The ALMA is the world's most powerful observatory for studying the universe at the long-wavelength millimeter and submillimeter range of light. It's designed to spot some of the most distant, ancient galaxies ever seen, and to probe the areas around young stars for planets in the process of forming. The site search process resulted in the selection of a very high, dry site in northern Chile at 5000m elevation. At this site, the water vapor in the atmosphere is minimal, and observations at frequencies up to 950 GHz (and even higher) are feasible. Also, the site is close to a paved highway and access is easy.

Fig.1 ALMA Telescope

Antennas: In ALMA there are 66 antennas, in which 54 are 12m and 12 are 7m dishes diameters are used. Their unique features are a spider-web feed support to hold the secondary mirror and an elevation gear that is driven by a track system. MELCO (Mitsubishi Electric Corporation) designed a 12-meter antenna with a bolted dish, spider-webbed feed legs, and a magnetic drive elevation gear. They also designed the twelve 7-meter dish antennas in miniature, but with the smooth, four-poled feed legs, that

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sit on the same pedestal drive bases as the 12-meter antennas. The surfaces of all of these dishes, to accurately reflect millimeter and submillimeter waves, are smooth to less than the thickness of a human hair.

Front End: The radio waves from space hit the dish and bounce up to the secondary mirror balanced precisely above. This mirror reflects the waves down into the heart of the telescope, called its Front End. Here the receivers can detect frequencies from 31 GHz up to 950 GHz [4].

TABLE 1 RECEIVER BANDS

| Band No. | Freq. Range (GHz) | Wave-length (mm) | Instantaneous Bandwidth (GHz) | Configuration |
|---|---|---|---|---|
| 1. | 31.3 - 45 | 6.7-9.6 | 1 × 8 | SSB |
| 2. | 67-90 | 3.3-4.5 | 1 × 8 | SSB |
| 3. | 84-116 | 2.6-3.6 | 2 × 4 | 2SB |
| 4. | 125-163 | 1.8-2.4 | 2 × 4 | 2SB |
| 5. | 163-211 | 1.4-1.8 | 2 × 4 | 2SB |
| 6. | 211-275 | 1.1-1.4 | 2 × 5.5 | 2SB |
| 7. | 275-373 | 0.8-1.1 | 2 × 4 | 2SB |
| 8. | 385-500 | 0.6-0.8 | 2 × 4 | 2SB |
| 9. | 602-720 | 0.4-0.5 | 2 × 8 | DSB |
| 10. | 787-950 | 0.3-0.4 | 2 × 8 | DSB |

Bands 1 and 2 will be developed in the future.
SSB - single sideband, DSB - double sideband
2SB - both sidebands detected separately

Correlator: ALMA's antennas do not work alone. They function as a whole of up to 66 antennas, separated by a varying distances. The collected data from different antennas is processed [5] inside the supercomputer, at speeds reaching 17 quadrillion mathematical operations every second, every antenna's signal is paired with every other antenna's signal.

Astronomers process those data in a new software package designed by radio astronomers and software developers for ALMA called CASA.

## III. NOBEYAMA RADIO OBSERVATORY

The Nobeyama Radio Observatory (NRO) at an elevation of 1,350 meters (4,430 ft) consists of three radio instruments located near Minamimaki, Nagano in Japan and it is a division of the National Astronomical Observatory of Japan (NAOJ). The 45m single-dish radio telescope that operates in short-millimetre wavelengths.

The Nobeyama Millimetre Array (NMA) interferometer consisting of six 10 m diameter telescopes and array of eighty-four antennas dedicated for solar observations [6].

This telescope has been used to observe large solar structures, such as the polar brightening or prominences. The large diameter of the telescope enabled us to observe, for the first time, a sunspot with enough spatial resolution to distinguish the sunspot umbra from the other regions at millimeter range. Solar filter was used to enable us to prevent saturation of the receivers.

Fig.2 Nobeyama Radio Observatory

Two Superconductor-Insulator-Superconductor (SIS) receivers (S80 and S100)[7] was used. These two receivers can be tuned at different frequencies and can receive radio emissions simultaneously. It was observed at 85 GHz (3.5 mm) and 115GHz (2.6 mm). Nobeyama 45-m Telescope is One of the largest Radio telescope which covering 20–115GHz.

## IV. VERY LARGE ARRAY (VLA) OBSERVATORY

The Very Large Array (VLA) is a radio astronomy observatory at an elevation of 2,133 meters (7,000ft) located on the Plains of San Agustin, between the towns of Magdalena and Datil, some 50 miles (80 km) west of Socorro, New Mexico.

The antennas and transporters of the Very Large Array were designed and built in the 1970s. Its 28 25-meter dishes are kept in Y-shaped array and all the equipment, instrumentation, and computing power to function as an interferometer.

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Table 2. Frequency Band Of Vla's 28 25-Meter Parabolic Dish Antennas That Use 10 Receivers

| Frequency | Bands | Frequency | Bands |
|---|---|---|---|
| 74 MHz | Band 4 | 8.4 GHz | X Band |
| 327 MHz | P Band | 15 GHz | Ku Band |
| 1.4 GHz | L Band | 22 GHz | K Band |
| 3 GHz | S Band | 33 GHz | Ka Band |
| 5 GHz | C Band | 43 GHz | Q Band |

Each of the massive telescopes is mounted on double parallel railroad tracks, so the radius and density of the array can be transformed to focus on particular bands of wavelength. Maximum bandwidth in each polarization is 0.1GHz and maximum number of frequency channels 512 are used[8].

Fig.3 Very Large Array (VLA**)**

The VLA is an interferometer; this means that it operates by multiplying the data from each pair of telescopes together to form interference patterns. we can take these patterns and use a mathematical technique called the Fourier transform to make maps.

## V. LA SILLA OBSERVATORY

The la Silla Observatory is an astronomical observatory at an elevation of 2,400 meters (7,874 ft) in Chile with three telescopes built and operated by the European Southern Observatory (ESO).

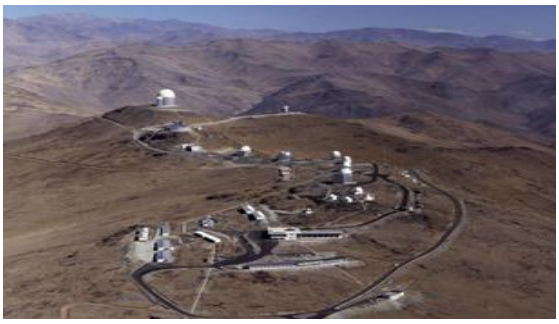

Fig.4 la Silla Observatory

The La Silla telescopes and instruments are located 150 km northeast of La Serena at the outskirts of the Chilean Atacama Desert, one of the driest and remotest areas of the world. Now hosts some of the world's most powerful facilities for the discovery of planets outside the Solar System. These include the HARPS spectrograph at the ESO 3.6-metre telescope, and the Swiss 1.2-metre Leonhard Euler Telescope, while the New Technology Telescope is still one of the best 4-metre-class telescopes in the southern hemisphere. Several telescopes are located at the site and are partly maintained by ESO. The observatory is one of the largest in the Southern Hemisphere and was the first in Chile to be used by ESO.Like other observatories in this geographical area, La Silla is located far from sources of light pollution and, like the Paranal Observatory, home to the Very Large Telescope, it has one of the darkest night skies on the Earth. [9].

## VI. VERY LARGE TELESCOPE (VLT) OBSERVATORY

The VLT Observatory is an astronomical observatory at an elevation of 2,635 meters (8,646 ft) in Chile. VLT was built to allow European astronomers and their colleagues worldwide to perform ground-breaking research in observational astronomy and cosmology. (VLT) is a telescope facility operated by the European Southern Observatory on Cerro Paranal in the Atacama Desert of northern Chile[10]. Operating a complex facility like the VLT and making sure that it is able to fulfill its enormous potential is not an easy task. Its carefully designed operations scheme, which involves specialized groups of scientists and engineers both in Chile and in Europe, is an essential component in the continued success of the VLT.

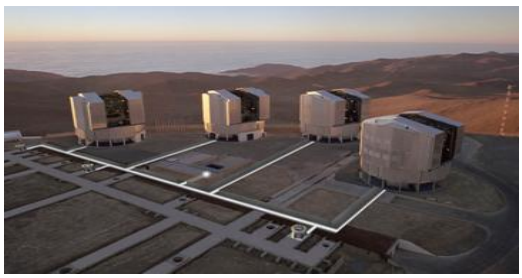

Fig.5 Very Large Telescope (VLT)

TABLE 3 INSTRUMENTS ON THE VLT

| Telescope name | Cassegrain-Focus | Nasmyth-Focus A | Nasmyth-Focus B |
|---|---|---|---|
| Antu | FORS2 | NACO | KMOS |
| Kueyen | X-Shooter | FLAMES | UVES |
| Melipal | VISIR | SPHERE | VIMOS |
| Yepun | SINFONI | HAWK-I | MUSE |

The VLT consists of four individual telescopes. The four separate optical telescopes are known as Antu, Kueyen,

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Melipal and Yepun, which are all words for astronomical objects in the Mapuche language[11]. Each telescope have a primary mirror 8.2 m across, which are generally used separately but can be used together to achieve very high angular resolution. The VLT operates at visible and infrared wavelengths.

## VII. KECK OBSERVATORY

The W. M. Keck Observatory is a two-telescope astronomical observatory at an elevation of 4,145 meters (13,600 ft) near the summit of Mauna Kea in the U.S. state of Hawaii. The two telescopes feature a highly capable suite of advanced instrumentation for both optical and near-infrared wavelengths, including imagers, multi-object spectrographs, high-resolution spectrographs, and integral-field spectroscopy. 10 m (33 ft) primary mirrors, currently among the largest astronomical telescopes in use [12].

The combination of an excellent site, large optics and innovative instruments has created the two most scientifically productive telescopes on Earth.

Fig.6 Keck Observatory

The Observatory also operates the only large-aperture infrared interferometer in the U.S. [13]

TABLE 4. COMPARISION OF OBSERVATORIES

| Specification | NOBEYAMA | VLA | LA SILLA | VLT | KECK | ALMA |
|---|---|---|---|---|---|---|
| **Organisation** | National Astronomical Observatory of Japan | National Radio Astronomy Observatory | European Southern Observatory | European Southern Observatory | California Association for Research in Astronomy dba W. M. Keck Observatory | European Southern Observatory, National Science Foundation, National Institutes of Natural Sciences, Japan |
| **Location** | Minamimaki, Nagano in japan | Socorro County, U.S. A. | Coquimbo Region, Chile | Paranal Observatory, Chile | Kamuela, Hawai i, United States | Llano de Chajnantor Observatory, Chile |
| **Altitude** | 1,350meters (4,430 ft) | 2,133 meters (7,000ft) | 2,400 metres (7,900 ft) | 2,635 metres (8,645 ft) | 4,145 metres (13,600 ft) | 5,058.7 metres (16,597 ft) |
| **Wavelength/ frequencies** | Shortmillimeter wavelengths (17–34 GHz) & 20–115GHz | radio, 0.7–400 cm (50 GHz–74 MHz) | Very high wavelength | 300 nm – 20 µm (visible, near- and mid-infrared) | Optical, near-infrared | 6.7-0.4mm (31.3-950GHz) |
| **Telescope Style** | beam waveguide antenna | Interferometer | ESO 3.6-metre, Danish National, REM Telescope | Ritchey-Chrétien | Reflector | Radio telescope, radio interferometer |
| **Number of antennas/ telescope** | A 45m single-dish, six 10m telescopes | Array of 27 dishes | 9 telescopes/ reflectors are used. | 4 optical telescopes | 2-telescope | 54_12-m and 12_7-m antennas |
| **Diameter** | 45m, 10m | 27×25 m | 8.2m | 4 x 8.2-m (UT) 4x1.8-m (AT) | 10 m (33 ft) each | 7 m, 12m |
| **Angular resolution** | 0.004°(maximum)(corresponds to visual acuity ~4) | (0.00005°-0.000001°) | 0.000083° | 0.000014° | 0.00001° to 0.0001°for individual telescopes, depending on target and instruments used | 0.000005°-0.0016°(10 km/baseline) |

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| **Collecting area** | 4000 $m^2$ | 13,250 $m^2$ (f/0.36) | 3.8$m^2$ (2200 mm free aperture) | - | 76 $m^2$ (820 sq ft) each | up to 7240 $m^2$, 460 + 450 $m^2$ |

(UT) Unit Telescopes,
(AT) moveable Auxiliary Telescopes

Basic comparisons of all observatories are show in table 4. This six observatories work in different frequency range. ALMA is a largest observatory and the world's biggest eyes on the earth. Now ALMA stands as a masterpiece of engineering, the most complex astronomical observatory ever achieved on Earth.

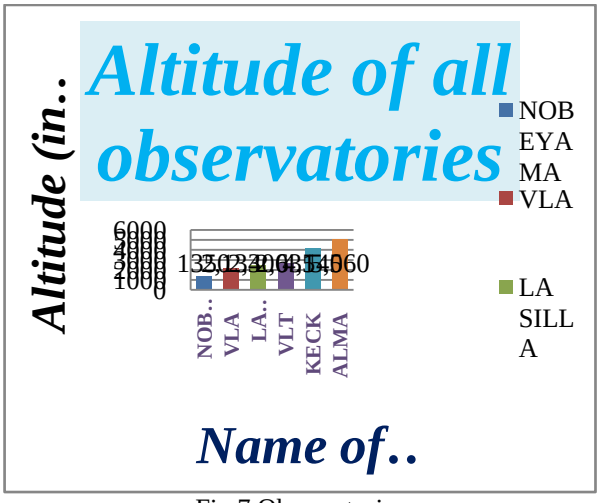


Fig.7 Observatories

Figure 7 shows the height of elevation from the sea level of Nobeyama Radio Observatory (NRO), Very Large Array (VLA) Observatory, La Silla Observatory, Very Large Telescope (VLT) Observatory, Keck Observatory and Atacama Large Millimeter Array (ALMA) Observatory.

## VIII. CONCLUSION

Nobeyama observatory is work in Shortmillimeter wavelengths 17-34GHz and 20-115GHz frequency range which used 45m single-dish, six 10m telescopes, and have diameter of antenna 45m, 10m. This gives the maximum angular resolution 0.004° corresponds to visual acuity ~4. Very large array (VLA) observatory is work in radio, 0.7–400 cm (50 GHz–74 MHz) frequency range and uses Array of 27 dishes, and have diameter of each 27 antennas is 25m. This gives the angular resolution 0.00005° to 0.000001°. LA SILLA observatory is work in Very high wavelength. In which 9 telescopes/ reflectors are used, and have the diameter of antennas 8.2m. This gives the angular resolution 0.000083°. Very large telescope (VLT) observatory is work in (300 nm – 20 μm) visible, near- and mid-infrared frequency range used 4 optical telescopes, and have the diameter of antenna 4x8.2m (UT) Unit Telescopes, 4x1.8m moveable (AT) Auxiliary Telescopes. This gives the angular resolution 0.000014°. KECK observatory is work in Optical, near-infrared frequency range. Which is used 2-telescope, and have the diameter of each antennas 10 m (33 ft). This gives the angular resolution 0.00001° to 0.0001°for individual telescopes that is depending on target and instruments used. Atacama Large Millimeter Array (ALMA) is the world's biggest eye on the sky. ALMA observatory is work in 6.7-0.4mm wavelength and (31.3-950GHz) frequency range, which is used 54_12-m and 12_7-m antennas, and have the diameter of antenna is 7 m, 12m This gives the angular resolution 0.000005°-0.0016°(10 km/baseline).

## REFERENCES

[1] John C. Webber, "The ALMA Telescope",National Radio Astronomy Observatory, 2015
[2] Jean L. Turner and H. Alwyn Wootten, "Atacama Large Millimeter/Submillimeter Array (ALMA)"Department of Physics and Astronomy, UCLA, Los Angeles, CA 90095-1547, USA
[3] Twilson and Wgarnier , "ALMA GLOBAL PROJECT" ALMA Newsletter, February 2009.
[4] J. Effland, S. M. X. Claude, G. A Ediss, P. Dindo, F. Jiang, "The ALMA North American Receivers", SOFIA Science Center, Universities Space Research Association, NASA Ames Research Center, Moffett Field, CA 94035, 2014.
[5] Alain Baudry and John Webber, "The ALMA 64-antenna Correlator: Main Technical Features and Science Modes",Université de Bordeaux 1, LAB, BP 89, 33270 Floirac (France) & European ALMA Project Office, ESo.
[6] Kazumasa Iwai1 and Masumi Shimojo,"Observation of Chromospheric Sunspot at Millimeter Range with the Nobeyama 45 m Telescope",National Astronomical Observatory of Japan, Mitaka, Tokyo 181-8588,Japan.
[7] Yasuhumi Sait1,Shigeru Takahash1, and Tomohisa Yonezu,"New Observing System of the 45-m Telescope at Nobeyama Radio Observatory", Osaka Prefecture University, 1-1 Gakuen-cho, Nakaku, Sakai, Osaka 599-8531, Japan.
[8] R. A. Perley, C.J.Chandler, B.J.Butler, and J.M. Wrobel," The Expanded Very Large Array – A New Telescope For New Science" arXiv:1106.0532v1 [astro-ph.IM] 2 June 2011
[9] A Window to the Past — La Silla's transformation through time". ESO Picture, March 2012. http://www.eso.org
[10] Trimble, V.; Ceja, J. A. (2010). "Productivity and impact of astronomical facilities", Received 2009 Nov 15, accepted 2010 Jan 3 Published online 2010 Mar 12.
[11] "Paranal Observatory Instrumentation". Retrieved 2015-10-09. http://www.eso.org.
[12] Sean Adkins1, Rachel Akeson3, Joshua Bloom4, Michael Bolte6, Judy Cohen2, "The W. M. Keck Observatory: A Private/Public Partnership Enabling Frontier Astrophysical Advances in the Coming Decade" Astro2010 Programs
[13] Taft Armandroff,'The Role of the W. M. Keck Observatory in U.S. Astronomy", Astro2010 Study Groups.